National Weather Service
Office of Meteorology

Technical Procedures Bulletin

Subject: Ocean Surface Wind Vectors Retrieved from Satellites with Scatterometers

Series No. 466

Science Division, Silver Spring, MD 20910

THIS IS A NEW BULLETIN ON THIS SUBJECT January 11, 2000

This bulletin, prepared by Mr. W. H. Gemmill, Mr. L. D. Burroughs, and Ms. V. M. Gerald of the Ocean Modeling Branch (OMB), Environmental Modeling Center (EMC), National Centers for Environmental Prediction (NCEP) and P. Woicheshyn of the Jet Propulsion Laboratory, describes "NCEP improved" ocean surface wind vector data retrieved from ERS scatterometer data at 10 m above the sea surface which is being prepared for distribution through AWIPS, FOS, and GTS in BUFR format.

These data are expected to become operational in late March 2000. They will be issued 4 times a day and contain 6 hours of data centered on the synoptic hours. The issuance times will be approximately 0415, 1015, 1615, and 2215 UTC. Only data from the European Space Agency's ERS2 satellite are currently available. In time data from other satellites with similar instruments will be added to the bulletins after they come on line and their data have been cleared for dissemination. ERS2 is a polar orbiter with an orbit time of 102 minutes with two orbits per day over any given area (one ascending and one descending). An active microwave C-band radar at 5 gHz with 3 one sided fixed antennae is used. It has a swath 500 km wide with a footprint resolution of 50 km and spacing at 25 km.

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OCEAN SURFACE WIND VECTORS RETRIEVED FROM SATELLITES WITH SCATTEROMETERS

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1. INTRODUCTION

Wind vector data have been available since 1992 as a fast delivery product from the European Space Agency (ESA) ERS polar orbiting satellites. The satellite flying currently is ERS2. The satellite carries three antennas but has a single sided look at the surface of the seas (see Table 1 for a summary of the ERS specifications). The scatterometer is an active satellite sensor which detects the loss of intensity of a transmitted signal from that returned by the ocean surface. The radar backscatter measurements are dependent on the ocean surface roughness and can be related to the ocean surface wind (or surface wind stress). Backscatter measurements are converted to wind vectors through the use of a transfer function or an empirical algorithm. These data provide wind vectors (speed and direction), with a relatively narrow swath coverage of 500 km with a footprint reolution of 50 km and spacing at 25 km. Unfortunately, the inversion process that converts satellite backscatter measurements into a wind vector, does not provide a single unique solution for the wind vector, but provides multiple vector solutions.

Table 1. Satellite ocean surface wind specifications for ERS Satellites.

Type	Polar Orbiter (~102 min/orbit)
Areal Coverage	Twice Daily (one ascending and one descending orbit)
Sensor	Active Microwave
Receptors	Three 1 sided fixed antennae
Measurement	Sigma-0
Frequency Bands	5 gHz C-band radar
Swath (km)	500
Number of Data Cells	19
Cell Footprint (km)	50
Range of Wind Speeds (m/s)	4 - 24
Speed Accuracy	2 m/s up to 20 m/s and 10 % above 20 m/s
Direction Accuracy	$\pm 20^{o}$
Algorithm used	CMOD4

2. DEVELOPMENT OF REPROCESSED VECTORS

Once the ESA "fast-delivery' wind vector data became available, It became obvious that there were serious problems with it. The standard accuracy specified for surface wind speed data is 2 m/s for wind speeds up 20 m/s, and 10% for wind speeds above that, and the accuracy for wind direction is 20 degrees. Gemmill *et al.* (1994) demonstrated that while the wind speed retrievals met the specification, the wind direction selections did not. The conclusion of that study was that the use of CMOD4 transfer function (already in use by ESA; Offlier, 1994) with the NCEP global ocean surface wind analysis field could produce wind vectors with acceptable accuracy. Table 2 shows a comparison between the ESA fast delivery wind vectors and the NCEP reprocessed wind vectors from the 1994 study. These reprocessed wind vectors have been available for assimilation into NWP models on an operational basis within NCEP since September 1994 (Peters *et al.*, 1994).

Table 2. Statistical comparison of ESA Fast Delivery ERS1 scatterometer wind vector data and NCEP reprocessed wind vector data against buoy data, for NDBC (mid-latitude) and TOGA (Tropical) buoys on the High Seas. The space window between satellite and buoy is 0.5 degrees, and the time window is ± 3 hours.

		ESA Fast Delivery Scatterometer Data		NCEP Reprocessed Scatterometer Data	
		Satellite	Buoy	Satellite	Buoy
Sample Size (matchups)		8755		9371	
Mean Speed (m/s)		6.5	7.0	6.3	6.9
Standard Deviation (m/s)		2.7	2.6	2.8	2.7
Maximum Speed (m/s)		20.0	20.1	20.0	20.1
Number of Calm Winds		0.0	72.0	0.0	107.0
Statistics based on Satellite Winds Minus Buoy Winds					
Wind Speed	**Bias (m/s)**	-0.50		-0.50	
	RMS (m/s)	1.70		1.80	
	Correlation	0.80		0.80	
Direction	**RMS (deg)**	57.00		31.00	
Vector Correlation(*)		0.71		0.87	

Notes: (*) The vector correlation used here was proposed by Crosby *et al,* 1993. The data was collected from 93/09/09 through 94/09/09.

An example of global coverage, from the ERS-2 scatterometer is shown in figure 1. Figure 2 shows an example of fast-delivery ESA wind vectors for a case along the Washington and Oregon coast. Figure 3 shows the same case, but with the NCEP reprocessed wind vectors. It can be immediately seen that the wind direction between the two wind plots are opposite to one another by 180 degrees along the Washington and Oregon coast. Figure 4 is included to show the sea level pressure analysis for the same time period as the satellite observations. It is clear that the NCEP reprocessed wind directions are more consistent with the sea level pressure analysis than the ESA real-time product.

The retrieval procedures (and codes) were provided through the U.K. Meteorological Office. The wind speed and direction solutions are first derived by using the same transfer function CMOD4 (Offiler, 1994) used by ESA. The vector solutions are then ranked according to a probability determined by the goodness of fit against the CMOD4 transfer function. Rufenach (1998) shows that a transfer function used alone cannot select the most correct wind vector. He shows that directions will be wrong by 180 degrees as often as the correct directions. Therefore, a background wind field from a numerical model is used to adjust the initial directional probabilities. The vector solutions are then re-ranked according to probability determined by including the influence of the background field. A final procedure (not used by ESA) is then carried out on the scatterometer wind swath to insure that all the winds present a reasonable and consistent meteorological pattern. This procedure, the sequential local iterative consistency estimator (SLICE), works by changing the directional probabilities (and rank) of each valid solution using wind directions from surrounding cells. The SLICE algorithm was developed and is being used by the U. K. Meteorological Office. At NCEP the global model 6-hour surface wind forecast is used for the background field. In contrast, the ESA "Fast Delivery" data product uses an 18 - 36 hour forecast from the ECMWF global model as a background wind field. Furthermore, ESA uses a model forecast to assist in ambiguity removal only when the initial first ranked probability is not greater than a given threshold. NCEP uses the background wind information in all the retrievals.

The use of the NCEP reprocessed ERS2 data in the global data assimilation began in November, 1995 (Caplan *et al.*, 1997).

3. PRODUCT DISSEMINATION

These data are presently on the Internet at http://polar.wwb.noaa.gov/winds four times a day for the Northwest Pacific and Northwest Atlantic with panels for ERS2 wind vectors, along with SSM/I neural network (see Gemmill *et al.*, 2000) ocean surface wind speeds, columnar water vapor, columnar liquid water data, ship and buoy data, and a sea level pressure analysis (see Fig. 5).

These data are expected to become operational in late March 2000 in BUFR format. They will be issued 4 times per day and contain 6 hours of data centered on the synoptic hours. They will include the following information:

1) Satellite ID
2) Year
3) Month
4) Day
5) Hour
6) Minute
7) Latitude
8) Longitude
9) Wind Speed
10) Wind Direction

The issuance times will be approximately 0415, 1015, 1615, and 2215 UTC. Global data from the European Space Agency's ERS2 satellite are currently available. In time data from other satellites with similar instruments will be added to the bulletins after they come on line and their data have been cleared for dissemination. ERS2 is a polar orbiter with an orbit time of approximately 102 minutes and has two orbits per day over any given area (one ascending and one descending). It has a swath 500 km wide with a footprint resolution of 50 km and spacing at 25 km.

4. REFERENCES

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FIGURES

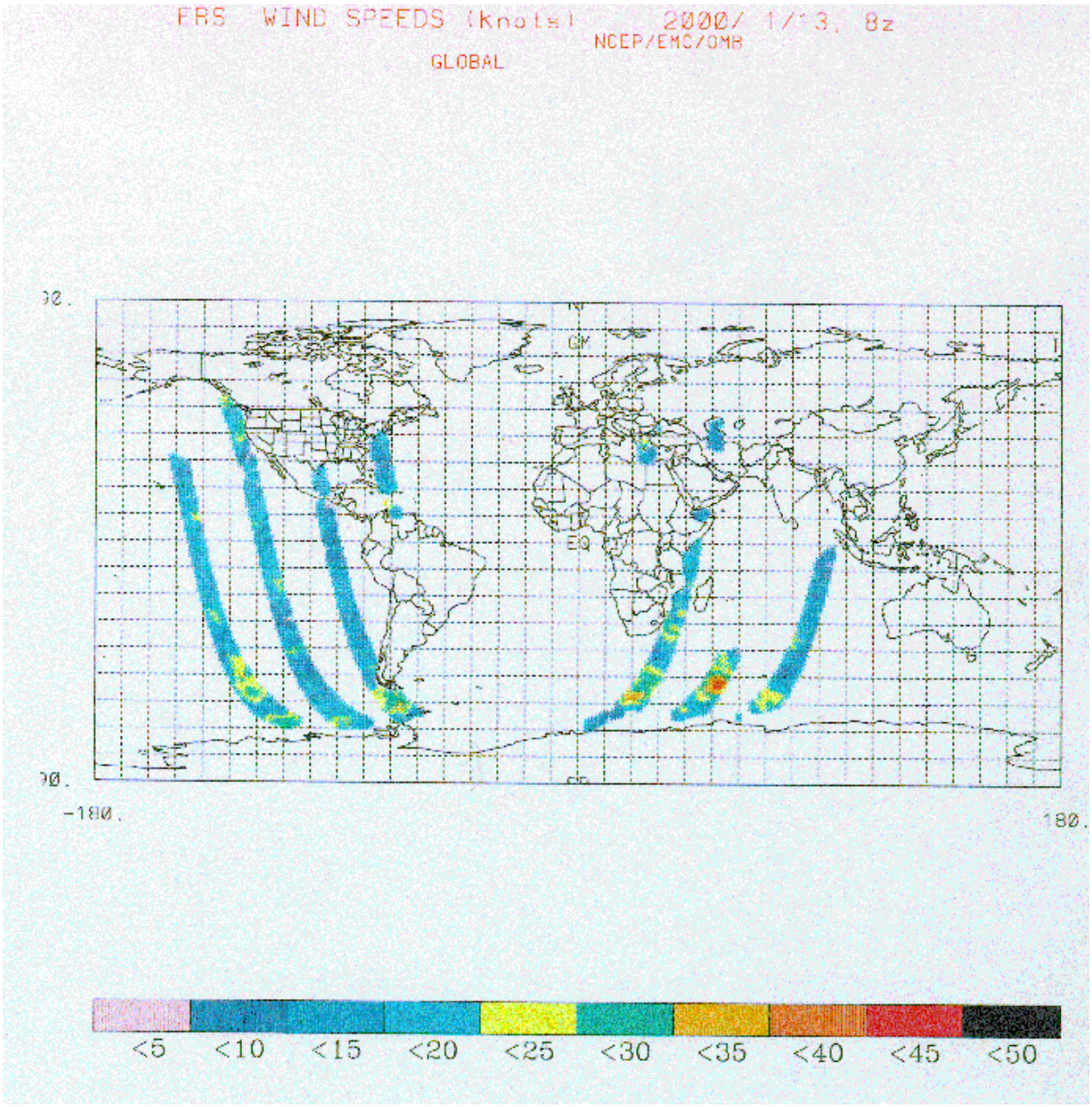

Figure1. Scatterometer wind vector coverage from satellite ERS-2 for January 5, 1998 for the six hour period from 0300 to 0900 UTC.

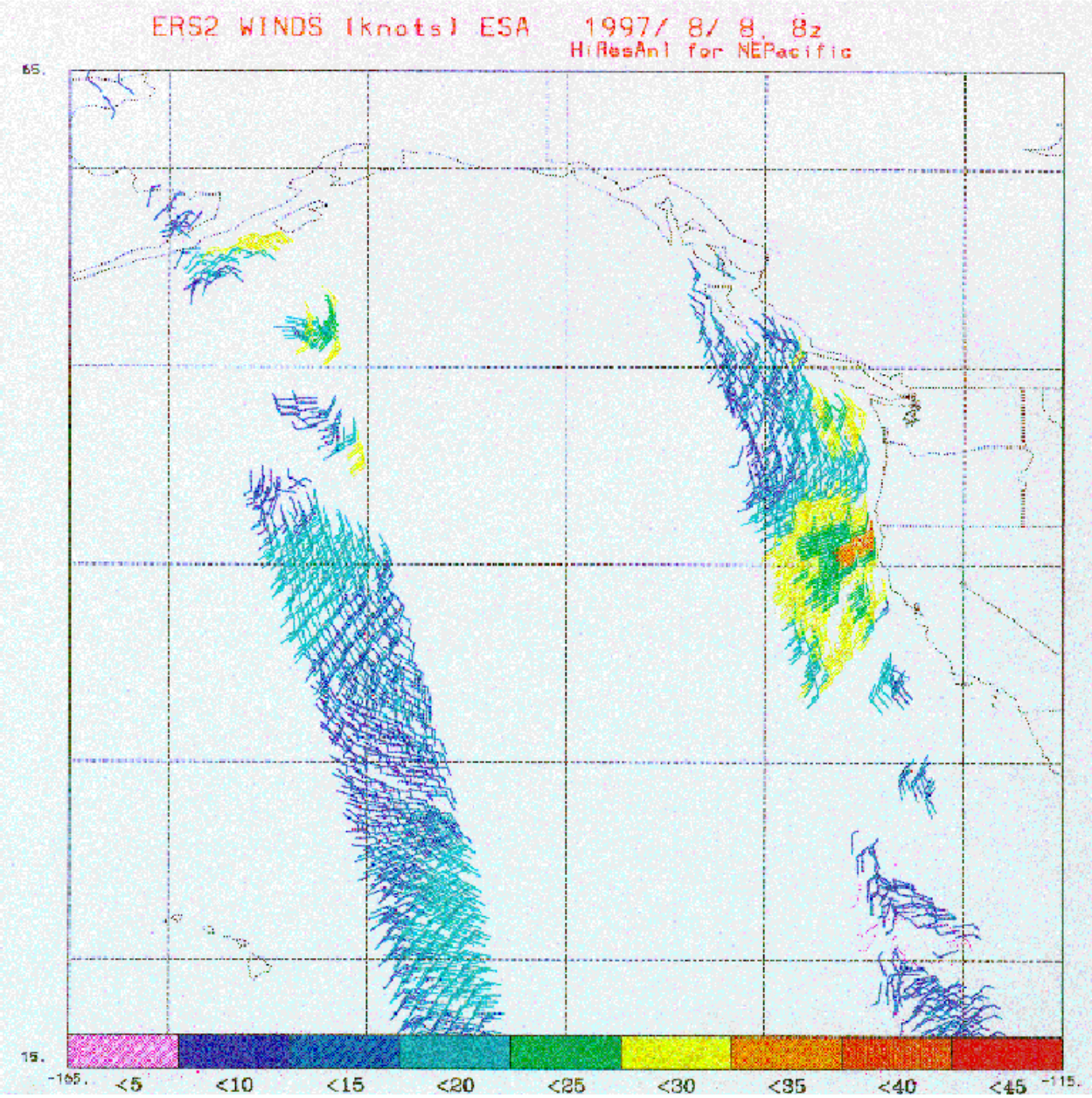

Figure 2. Example of "Fast Delivery" ESA processed scatterometer wind vectors for August 8, 1997 around 0800UTC

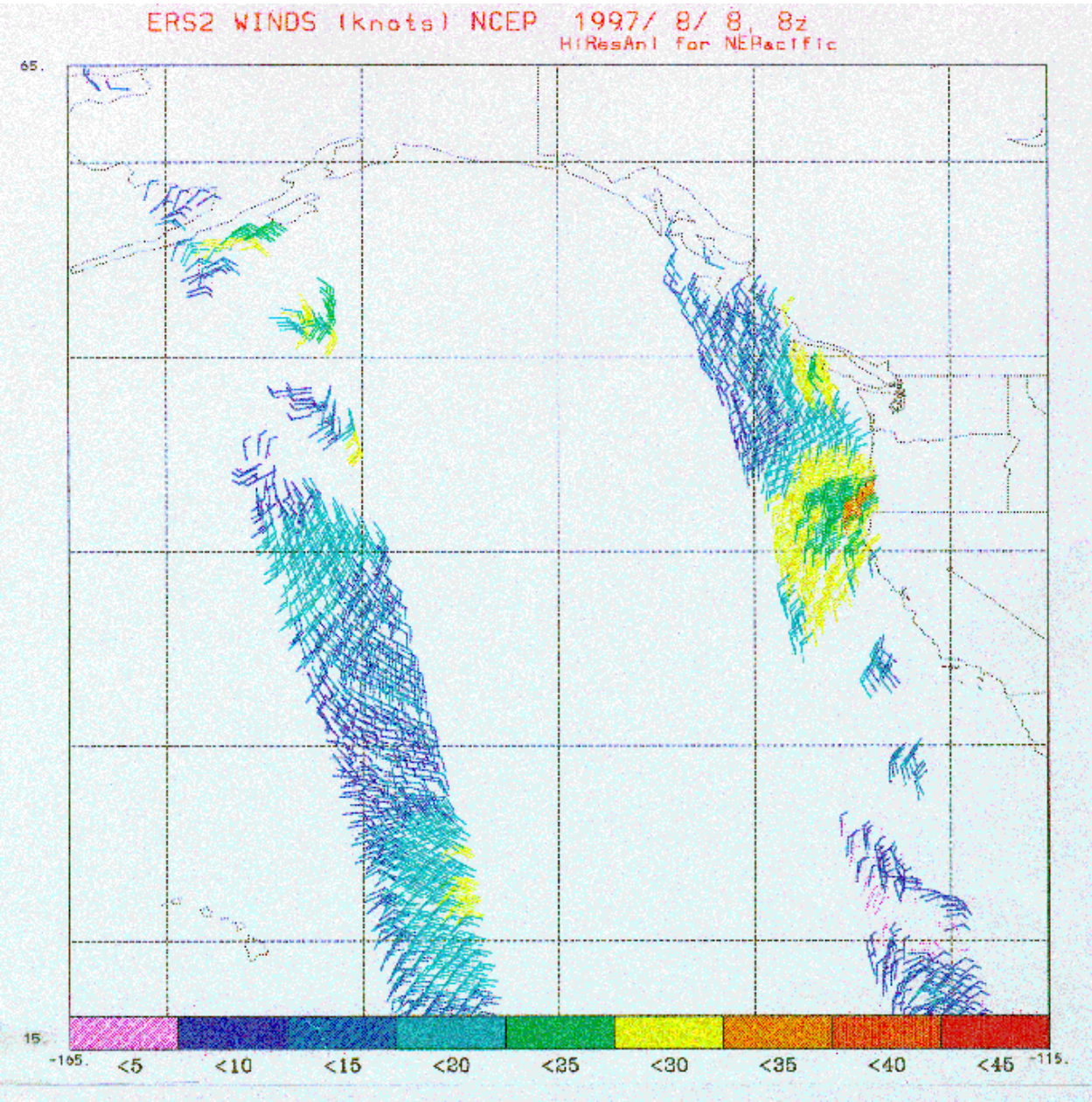

Figure 3. Example of NCEP reprocessed scatterometer wind vectors for August 8, 1997 around 0800UTC

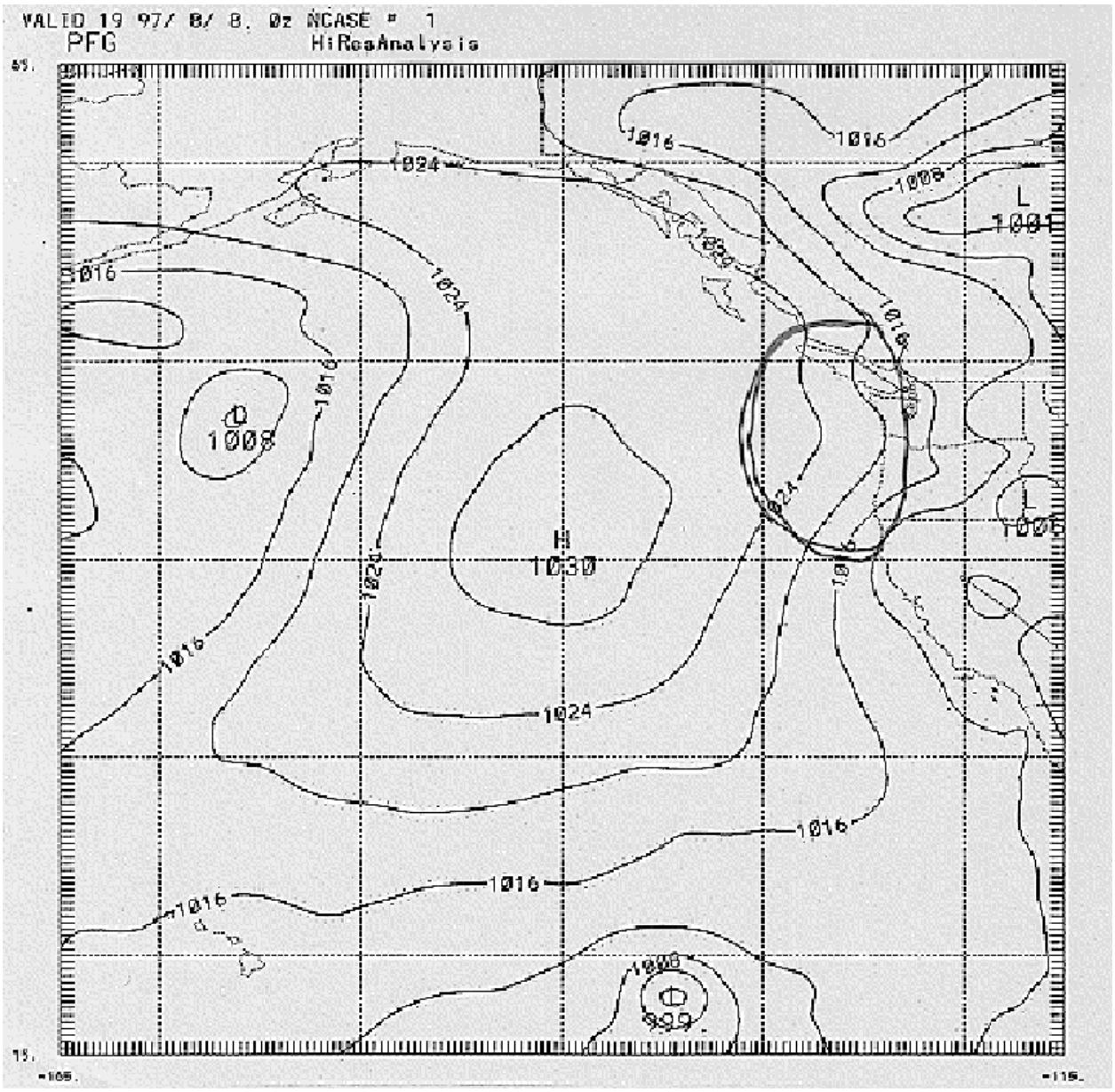

Figure 4. Sea level pressure (hPa) analysis for 00 UTC August 8, 1997.

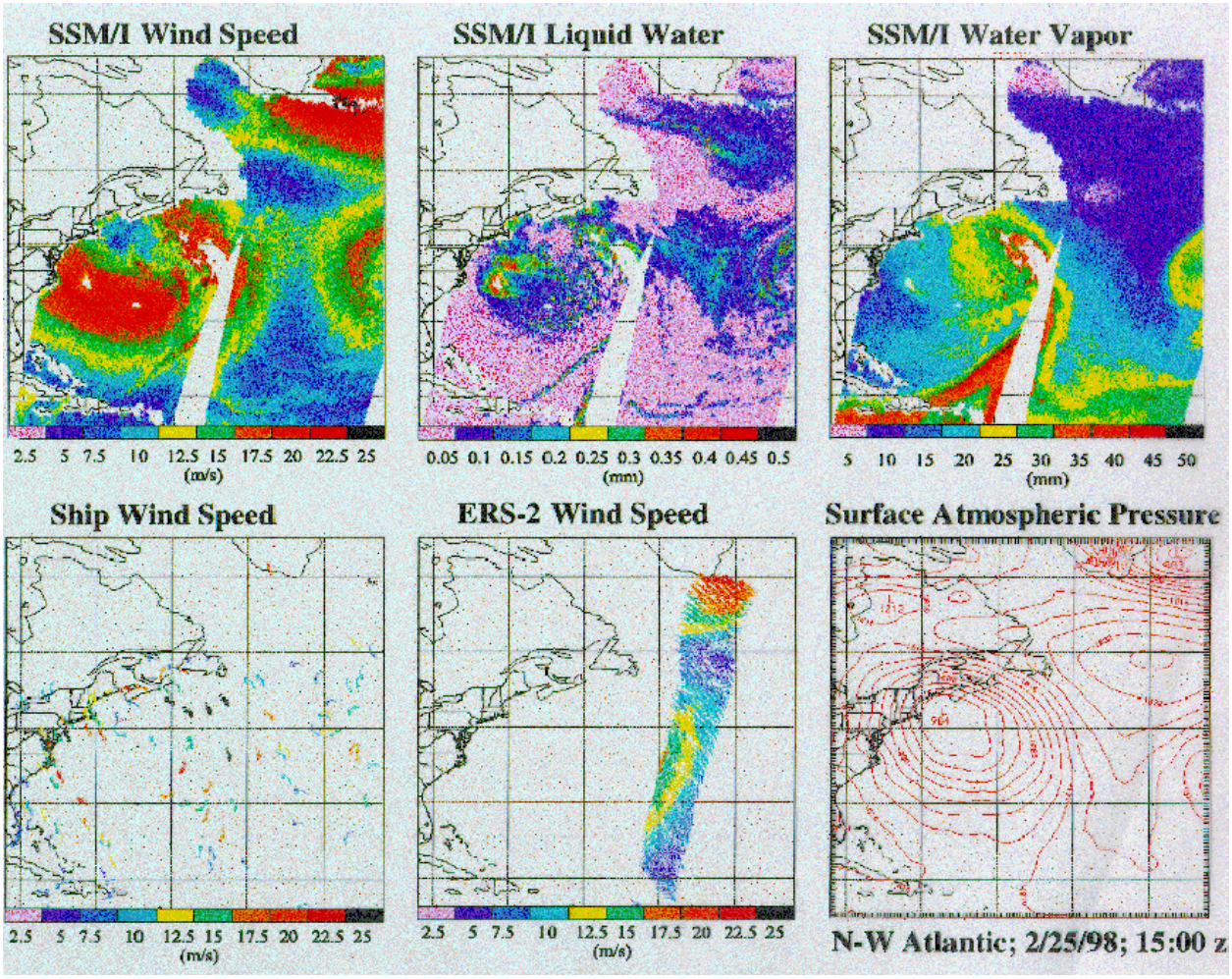

Figure 5. Satellite and other data depicted on the winds web page. upper left - SSMI Wind Speed, upper center - SSMI Liquid Water, upper right - SSMI Water Vapor, lower left - Ship Winds, lower center - ERS2 Winds, and lower right - Surface Pressure Analysis.